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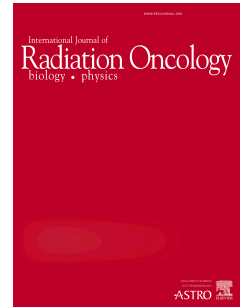
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# Accepted Manuscript

Hospital quality factors influencing the mobility of patients for radical prostate cancer radiotherapy: a national population based study

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## Hospital quality factors influencing the mobility of patients for radical prostate cancer radiotherapy: a national population based study

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**Conflicts of Interest**

Heather Payne has worked as a consultant and has been paid for lectures and received hospitality to travel to meetings from Janssen, Astellas, Ferring, Sanofi Aventis, Novartis.

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Hospital Episode Statistics were made available by the NHS Health and Social Care Information Centre (© 2012, Re-used with the permission of NHS Digital. All rights reserved.)

Data for this study is based on patient-level information collected by the NHS, as part of the care and support of cancer patients. The data is collated, maintained and quality assured by the National Cancer Registration and Analysis Service, which is part of Public Health England (PHE). Access to the data was facilitated by the Public Health England's Office for Data Release.

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**Role of the Funding Source**

The study sponsors had no role in the design of the study; the collection, analysis, or interpretation of the data; the writing of the manuscript; or the decision to submit for publication. The views expressed in this publication are those of the authors and not necessarily those of the NHS, the NHS National Institute for Health Research, or the Department of Health.

**Summary**

Using geographic information systems and econometric modelling we present the first national study evaluating the hospital quality factors that attract patients for radiotherapy treatment in health-care markets. We found that one in five men bypassed their nearest radiotherapy centre for treatment, especially those who were younger, and more affluent. In the absence of indicators reflecting treatment quality, centres that were early adopters of intensity modulated radiotherapy or that offered shorter hypofractionated treatment schedules were more attractive to patients.

**Abstract****Introduction**

Patient choice policies have been introduced across publicly funded health systems to give patients more control over their care, and to encourage quality improvement amongst providers. To date we have no empirical evidence that patients requiring radiation treatment are prepared to travel to alternative more distant centres or the factors that influence this.

**Materials and Methods**

We present the results of a national cohort study using administrative hospital data for all 44,363 men who were diagnosed with prostate cancer and underwent radical radiotherapy in the English National Health Service between 2010 and 2014. Using geographic information systems we investigated the extent to which men choose to travel beyond ("bypass") their nearest radiotherapy centre and conditional logistic regression to estimate the effect of hospital and patient characteristics on this mobility.

**Results**

20.7% ( $n=9,161$ ) of men bypassed their nearest radiotherapy centre. Travel time had a very strong impact on where patients moved to for their treatment, but its effect was smaller for men who were younger, more affluent, and from rural areas ( $p$  for interaction always  $<0.001$ ). Men were prepared to travel further to hospitals that offered hypofractionated prostate radiotherapy as their standard schedule (odds ratio 3.19,  $p<0.001$ ), to large-scale radiotherapy units (odds ratio 1.56  $P<0.001$ ) and to hospitals that were early adopters of intensity modulated radiotherapy (odds ratio 1.37,  $p<0.001$ ).

**Conclusion**

Men with prostate cancer are prepared to bypass their nearest radiotherapy centres. They are more likely to travel to larger established centres and those that offer innovative technology and more convenient radiotherapy schedules. Indicators, which accurately reflect the quality of radiotherapy delivered are needed to guide patients' choices for radiotherapy treatment. In their absence, patient mobility may negatively affect the efficiency and capacity of a regional or national radiotherapy service and offer perverse incentives for technology adoption.

**Key Words**

Patient Choice; Hospital Competition; Patient mobility; Technology adoption; Cancer; Equity

## INTRODUCTION

Many countries have introduced policies that allow patients to choose the hospital where they have their treatment.<sup>1,2</sup> Patients are expected to choose a hospital that delivers better quality care, and the resultant competition between providers as they attempt to attract new patients is expected to stimulate improvements in quality. However, for complex treatments such as radiotherapy we have no data to support whether patients are prepared to travel to alternative more distant centres, or the quality factors which influence this.

It is also debateable whether such policies are relevant in cancer care given the increasing centralisation of cancer services which, by its nature, will reduce the choices available to patients.<sup>3,4</sup> Treatment decisions are complex and the therapy itself may last for months resulting in significant physical and financial burden for those considering treatment at a more distant hospital. Furthermore, there is a lack of valid performance indicators, which accurately reflect the quality of cancer treatment, especially radiotherapy.

However, radiotherapy has seen a relentless diffusion of new technologies over the last decade, which has shaped clinical practice in both the targeting and delivery of treatment. It has been suggested that in certain health care markets, clinicians and hospital providers are encouraged to diversify practice through the integration and marketing of new high cost technologies (e.g. proton beam therapy) in order to attract new patients. However, this has been largely anecdotal with little or no evidence in publicly funded health systems.<sup>5,6</sup>

Using linked patient-level national datasets, geographic information systems, and applied econometric modelling, we investigated whether prostate cancer patients, who had radical



radiotherapy in the English National Health Service (NHS) “bypassed” their nearest radiotherapy provider for treatment, as well as the provider and patient characteristics associated with that mobility.

The NHS provides an ideal system for understanding the impact of patient choice policies. It is a national single-payer tax-based system where care is free and not based on ability to pay for insurance or treatment. The costs of services are fixed under a national tariff and providers are therefore expected to compete on quality and not price.<sup>7</sup> Patients have access to all available NHS providers in England with no explicit restrictions on the choices available.

## MATERIALS AND METHODS

We obtained individual patient-level data on all patients diagnosed with prostate cancer between 1<sup>st</sup> January 2010 and 31<sup>st</sup> March 2014 who subsequently underwent radiotherapy in the English NHS. Data was retrieved from the National Cancer Registration and Analysis Service (NCRAS) and linked at patient level to the National Radiotherapy Dataset (RTDS) and Hospital Episode Statistics (HES).<sup>8,9</sup> Patients who underwent radiotherapy in the private sector were not included in the analysis (<10% of eligible patients).

The RTDS provided information on each patient’s radiotherapy treatment: start and finish dates, treatment site (primary +/- regional nodes), total dose, number of fractions, and radiotherapy technique (Intensity modulated radiotherapy versus 3D conformal radiotherapy). The NCRAS dataset provided information on cancer stage and the HES dataset on age and comorbidities. Cancer severity was categorised according to a modified D’Amico classification system.<sup>10 11,12</sup> The patients’ place of

residence was available as the Lower Layer Super Output Area (LSOA), a geographic area that typically includes 1,500 residents or 650 households.<sup>13 14</sup>

#### *Travel times*

The population weighted centroids of the patients' LSOAs (used to define patient residence) and the full post-codes for the hospitals where the radiotherapy was undertaken were inputted into a geographical information system (ESRI ArcGIS 10.3) to calculate travel times according to the fastest route by car (using Ordnance Survey MasterMap Integrated Transport Network).

#### *Assessment of mobility*

All radiotherapy treatment provider (n=57) were ranked according to the distance in terms of drive time by car from the patient's residence. The proportion of patients not receiving care at their nearest provider (ranked >1) were considered to be "by-passers".<sup>15</sup>

We identified for each radiotherapy centre the number of patients for whom that centre was nearest but who had their treatment elsewhere - "leavers" – and also those patients for whom another radiotherapy centre was nearest but who had their radiotherapy at that centre – "arrivers". A centre was identified as being a "winner" or "loser" of patients if the difference between arrivers and leavers was statistically significant.<sup>16</sup> Patients receiving radiotherapy at their nearest centre were defined as "core users".

#### *Competition indices*

For each centre we also calculated a spatial competition index (SCI) as a measure of "external competition".<sup>17,18</sup> The SCI provides a uniform metric which can be used across all centres in England

to factor in the demand for services and the availability of alternative hospitals for patients to choose. In this analysis, the SCI for a radiotherapy centre was calculated based on both the number of eligible patients within a 60-minute drive and the number of alternative radiotherapy centres within 60-minute drive for each eligible patient:

$$SCI_i = 1 - \frac{1}{n_i} \sum_{j_i=1}^{n_i} \frac{1}{k_{j_i}}$$

where radiotherapy centre  $i$  has  $n$  eligible patients within a 60-minute drive and patient  $j$  in centre  $i$  has  $k$  alternative radiotherapy centres within a 60-minute drive. The SCI ranges theoretically from 0 for centres in a monopoly environment to a value close to 1 for centres in the most competitive environment.

#### *Patient characteristics*

Four patient level variables were derived from the linked dataset. First, patient age at the time of prostate cancer diagnosis. Second, the RCS Charlson Score, was used to identify the number of co-morbidities.<sup>19</sup> Third, the Index of Multiple Deprivation (IMD), was used as a measure of the patients' socio-economic deprivation.<sup>20</sup> The IMD was stratified into quintiles according to the national distribution such that 1 represents households in the 20% least deprived and 5 in the 20% most deprived LSOAs. Fourth, the patients' area of residence was classified as urban or rural.<sup>21</sup>

#### *Hospital characteristics*

At the start of the study, there were 52 radiotherapy centres across England. A further five centres opened during the study period. In the absence of publicly reported performance indicators for prostate cancer radiotherapy, we created four hospital-level variables as proxies for quality, which may make a hospital more attractive to patients when considering where to have radiotherapy

treatment. These variables were informed by the peer-reviewed literature, in-depth qualitative interviews undertaken by the study team with men previously treated for prostate cancer in the UK, and The National Prostate Cancer Audit organisational survey.<sup>22</sup>

We identified the 28 “university teaching hospitals”, based on their membership of the Association of UK University Hospitals.<sup>23</sup> Studies have demonstrated that teaching hospital status is associated with higher quality for certain interventions compared to non-teaching hospitals and therefore maybe preferentially chosen by patients.<sup>24-28</sup>

Second, we labelled the three hospitals that were delivering intensity-modulated radiotherapy (IMRT) as a standard of care at the start of the study period (2010) as “early IMRT adopters”. There was emerging evidence at the time that this technique delivered improved outcomes (reduced pelvic toxicity) relative to standard 3D conformal techniques.<sup>29,30</sup> In addition, IMRT was already a standard of care in countries such as the US in 2010 which may have prompted patients to seek treatment at centres that offer this technique in the NHS.<sup>29,30</sup>

Third, we identified eight centres which we classified as “large scale radiotherapy units” based on the number of Linear accelerators onsite. The median number of Linear accelerators across the 57 English NHS radiotherapy centres was 4 (range 2-12).<sup>31</sup> Centres with  $\geq 8$  linear accelerators onsite i.e. in the top quintile based on the distribution of Linear accelerators were considered to meet this criteria. These centres may have been considered preferentially by patients due to their large capital and staff infrastructure investment towards radiotherapy facilities or wider reputation effects from being regional centres.

Fourth, we identified four centres that were delivering hypofractionated radiotherapy (i.e. higher dose per treatment delivered over fewer total number of attendances) as their standard dose-fractionation regimen for prostate cancer at the start of the study period in 2010. Whilst a dose of 74 Gray delivered over 37 treatments remains the standard of care, hypofractionated regimens halve the duration of treatment from eight weeks to four weeks.<sup>32,33</sup>

### *Statistical analysis*

We used conditional logit regression to model the odds that a patient moved to a particular hospital as a function of travel time and hospital and patient characteristics.<sup>34,35</sup> We created a data set that included for each patient a row for each hospital providing prostate cancer radiotherapy at the time of treatment (number of hospitals varied between 52 and 57 as five hospitals opened during the study period). The dependent variable of the conditional logit model was a dummy variable with a value of 1 for the hospital where a patient had his treatment and a value of 0 otherwise.

Travel time was included in the model as the additional time men had to travel beyond their nearest hospital to an alternative hospital providing radiotherapy. In this way, we accounted for the variation in service configuration across England. Per definition, additional travel time was 0 minutes if a patient had his radiotherapy in the nearest radiotherapy centre.

First, we modelled the effect of travel time and individual hospital characteristics on the odds of moving to a particular hospital as part of a univariate analysis. In the second model, we included both hospital characteristics and travel time as part of a multivariate conditional regression model. In the third model, we included travel time, hospital characteristics and the interactions of patient characteristics with travel time. Patient characteristics included age, comorbidity, socioeconomic

background, and urban or rural residence. We present the results of both models in Tables 3 and 4.

Stata version 14 was used to undertake the statistical analyses.

## RESULTS

### *Patient population*

We identified 46,654 men diagnosed with prostate cancer between 1<sup>st</sup> January 2010 and 31<sup>st</sup> March 2014 who subsequently received radiotherapy (Supplementary Material - Appendix 1). Of these men, 44,860 received radical radiotherapy. 497 men were excluded as they lived outside England or could not be assigned to a NHS radiotherapy provider. The final study cohort comprised 44,363 men and patient characteristics are presented in Table 1.

### *Patient mobility*

9,161 men (20.7%) “bypassed” or travelled beyond their nearest radiotherapy centre to an alternative more distant centre (Table 2). 5142 men (12.6%) bypassed only one centre and 1,125 men (2.5%) bypassed five or more centres for treatment (Table 2). Figure 1 demonstrates the net gains and losses of patients by individual prostate cancer radiotherapy centres (n=57) due to patient mobility during the study period. 19 out of the 57 centres (33.3%) were classified as “winners” and 25 out of 57 centres (43.9%) “losers”. 13 centres had no statistically significant net gain or loss of patients. Some of the “winners” were treating 500 or more patients than expected if they had been operating solely on men for whom they were the nearest centre. Conversely, some of the “losers” were treating nearly 400 fewer procedures than expected. When considering the degree of external competition faced by each centre, centres experiencing the largest net gains or losses were predominantly located in the most competitive areas (SCI between 0.70 and 1) (Figure 2).

*Impact of travel time and patient and hospital characteristics on patient mobility*

Travel time had a very strong impact on the odds that a patient travelled to a particular hospital to receive radiotherapy in the univariate and multivariate conditional regression models (Tables 3 and 4). The odds of a patient travelling to a hospital that was up to 10 minutes further away than the patient's nearest radiotherapy provider was found to be on average 72% smaller (OR of 0.28) according to a conditional logit model that only included additional travel time (Table 3, Model 1). The odds of a patient travelling to a particular hospital decreased markedly as the additional travel time increased.

The results of the univariate analysis assessing the impact of hospital characteristics on the odds of travelling further to a particular hospital are presented in Table 3 (model 1). When considering the impact of hospital characteristics on mobility patterns of patients as part of a multivariate regression model including travel time and patient characteristics, men were 3.19 times more likely to travel to a particular radiotherapy centre if it offered hypofractionated radiotherapy as standard (Table 4, Model 3). In addition, patients were 1.56 times more likely to travel to a centre classified as a large-scale radiotherapy unit, and 1.37 times more likely to travel to a centre if it was an established IMRT centre. There was a small but significant increase in the likelihood that patients travelled to a specific centre if it had university hospital status (OR 1.19).

The addition of patient characteristics as interaction terms into our model showed that the impact of travel time was smaller for men who were younger, and for those who lived in more affluent or rural areas because the odds ratios expressing the interaction terms are greater than 1 (Table 4, Model 3). The greater the size of the interaction term value the larger its attenuating effect on the impact of travel time. For example, compared to having the radiotherapy at the nearest provider, for men classified as living in urban and less affluent areas, who are  $\geq 65$ , and have comorbidities, the odds of

travelling to a hospital that was up to 10 minutes further away was estimated to be 82% smaller (OR 0.18). The corresponding figure for men from rural areas (keeping all other patient characteristics the same as described) is 60% smaller (OR 0.40 =  $0.18 \times 2.23$ , based on multiplying the odds ratio of the main effect of additional travel time with the odds ratio of the interaction term). This implies that men from rural areas have a greater odds of travelling to an alternative hospital up to 10 minutes further away compared to men from urban areas. Different patient characteristics attenuate the effect further. For example, men from both rural and affluent areas (positive interaction terms) have an even greater odds of travelling to an alternative hospital up to 10 minutes further away (keeping all other patient characteristics the same), OR 0.51 ( $= 0.16 \times 2.23 \times 1.26$ ), compared to men from urban and less affluent areas.

## DISCUSSION

There is limited evidence about what factors inform and influence cancer patients' choice of treatment provider.<sup>1</sup> In this study, we demonstrate that in the UK NHS, one in five patients who have radiotherapy treatment "bypass" their nearest radiotherapy centre. Travel time had a very strong impact on where patients received their treatment but this effect was smaller for men who were younger, more affluent or living in rural areas. Men were more likely to travel to centres that offered shorter hypofractionated radiotherapy regimens as standard for prostate cancer, larger established radiotherapy units, and those centres that utilized IMRT earlier. Mobility between providers resulted in winners and losers, with some centres treating hundreds more patients each year than expected if they only treated local patients.

These findings are relevant across a range of elective secondary care cancer services in countries that have introduced patient choice of provider policies.<sup>1</sup> A substantial number of patients were



prepared to bypass their nearest radiotherapy centre despite the absence of comparative provider level performance information relating to the quality of radiotherapy treatment and the prolonged duration of treatment.

The routine availability of hypofractionated radiotherapy for prostate cancer was the strongest hospital-level driver of patient mobility. It is not possible to say whether patients were prepared to travel further to these centres because hypofractionated radiotherapy is more convenient or because patients considered these centres to be innovative and therefore potentially better.<sup>36</sup> However, the potential desire for treatment of shorter duration, correlates with our study findings that travel time has a very strong impact on the choices that patients make. In addition, previous research has shown that patients are reluctant to undergo radiotherapy compared to other prostate cancer treatment modalities due its prolonged duration.<sup>37</sup>

Patients in our cohort were more likely to travel to the three centres labelled as early adopters of IMRT despite rapid expansion in the availability of IMRT across centres in England during the study period.<sup>38,39</sup> This suggests that there is a wider reputation effect associated with being an early adopter of innovation, and that patients may have considered these centres to be at the forefront of technology.<sup>40,41</sup> To illustrate this point, all three established IMRT centres were also amongst the first adopters of stereotactic body irradiation (SBRT) in England.<sup>12</sup> Similarly, patients were more likely to travel to larger scale radiotherapy units, which may have had a wider reputation as being a regional centre of excellence for radiotherapy or cancer care more generally.

The patterns of mobility observed has resulted in large and unexpected shifts in market share. Radiotherapy centres located in the most competitive areas had significant gains and losses of

patients (Figure 2). In the NHS, funding follows the patient,<sup>7</sup> and therefore centres losing patients may have to cease providing that service due to lost income. Such an eventuality has already transpired for surgical centres providing radical prostatectomy, several of which have closed in the last five years.<sup>42</sup> This pattern of winners and losers also highlights the inefficiency and wasted capacity within the current radiotherapy service, which may further increase as a result of the current drive towards opening new radiotherapy centres across England (five opened during the study period) to improve access to treatment. Equally the impact on service capacity (e.g. waiting times) needs to be considered for those centres treating significant numbers of out of area patients.

#### *Appropriate implementation of advanced radiation technologies*

In the absence of performance indicators, centres that diversify their clinical practice (for example, through the integration of new technology), are potentially more attractive to patients. In the US, competition has been a key driver in the rapid expansion of innovative radiation therapies such as IMRT, proton beam therapy, and Cyberknife® for the management of prostate cancer to maintain market share and attract new patients. This has occurred at significant additional cost without any clear evidence for benefits to patients over existing standards of care.<sup>6,30,43-46</sup>

To avoid similar patterns of technology adoption for radiotherapy across different health systems, we recommend the use of formal health technology assessment (HTA) processes to support decision making regarding the integration of new technologies in publicly funded systems.<sup>5,47</sup> In contrast to new cancer drugs, radiotherapy has remained beyond the remit of HTA.<sup>5</sup> The Health Economics in Radiation Oncology project, which is being carried out under the auspices of the European Society for Radiotherapy and Oncology, is attempting to define economic frameworks for assessing the clinical and economic benefit of new radiotherapy technologies is still in its infancy.<sup>48</sup>

There is also a necessity to develop valid performance indicators for radiotherapy to guide patient decision-making and potentially stimulate improvements in treatment outcomes through “quality competition” as patients are responsive to perceived differences in quality.<sup>49</sup> This is important, given the increasing reliance on unsubstantiated web and media based cancer information, especially for new technologies.<sup>50,51 52</sup> A series of process indicators have been proposed by professional bodies, but these are hard for patients to interpret.<sup>53,54</sup> Whilst outcome measures are preferable an important caveat is that these can only be published following a lag period (for example, toxicity measures at one and five years).<sup>55</sup>

#### *Methodological limitations*

Our modelling of patient mobility used centroids of the LSOAs, small geographical regions typically made up of approximately 650 households, to represent the location of the patients’ residence. This approach has been used in previous studies of patient mobility in England.<sup>56</sup> However, it is likely that the noise added to the travel times will have attenuated rather than enhanced the observed relationships. Our model uses average drive times, which is the standardised methodology for these analyses and considered superior to straight-line distance. However, we do acknowledge that drive times are variable depending on the time of day, which may affect patient’s decision-making. In addition, public transport time were not available for this analysis.

We have not included waiting time as a factor influencing provider choice, as these were not publicly available for individual centres. Some patients may have considered moving to alternative providers to receive quicker treatment, however extensive efforts have been made in the English National Health Service to ensure prompt diagnosis and treatment of suspected cancer patients through a system of defined targets.<sup>57,58</sup> In 2014/2015 95.3% of people treated for urological cancers in the NHS began their first definitive treatment within the 31 day target.<sup>59</sup> Other potential determinants

of mobility such as care giver/work location were not available in our dataset, and we were unable to assess the effect of disease severity due to incomplete staging data. However, the overall impact on our observed patterns of mobility is likely to be small in the context of up to 20% of patients bypassing their nearest provider. The overall predictive probability of our model, despite these exclusions is very high, 82% (note models with values above 60% for goodness of fit estimation are considered to have a high degree of explanatory power).<sup>60</sup>

## CONCLUSIONS

Men with prostate cancer are prepared to bypass their nearest provider for radical radiotherapy, particularly those who are younger and more affluent. They are more likely to travel to larger established centres and those that offer innovative technology and shorter radiotherapy schedules. Patient mobility varies significantly across regions and between centres and is mainly evident in areas where competition between providers is strongest. This in itself implies that competition as a mechanism to stimulate improvements in the quality of care can only work in specific parts of the country. Indicators, which accurately reflect the quality of radiotherapy delivered, are essential in order to guide patients' choices for radiotherapy treatment. In their absence, patient mobility may negatively affect the efficiency and capacity of regional or national radiotherapy services and offer perverse incentives for technology adoption even in publicly funded health systems.

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**FIGURE CAPTIONS**

**Figure 1.** Net gain and losses of patients by each radiotherapy centre (blue bars) due to patient mobility between 2010-2014

**Figure 2.** Graph demonstrating the impact of competition (measured by the SCI Index) on the net gain or loss of patients for radiotherapy centres between 2010-2014.

**Key:** *SCI score = 0* Hospital facing weakest competition *SCI score =1* Hospital facing strongest competition; **Size of circle** = Number of men expected to have radiotherapy at centre; **Blue** = Centres classified as “Winners”; **Green** = Centres classified as “Losers”; **Orange** = Centres with no statistically significant gain or loss of patients; **Red** = Centres offering hypofractionated radiotherapy as standard.

**Table 1.** Characteristics of 44,363 men undergoing radical radiotherapy between 2010 and 2014 in the English NHS.

	Number	%
<b>Age (years)</b>		
<65	12,951	29.2
65-69	9,453	21.3
70-74	12,373	27.9
≥75	9,586	21.6
<b>Cancer severity</b>		
Advanced	620	1.8
Locally advanced	19,037	55.6
Intermediate localised	13,292	38.8
low risk localised	1,276	3.7
Insufficient staging information (n=10,138)		
<b>Number of comorbidities</b>		
0	34,368	77.5
≥1	9,995	22.5
<b>Index of Multiple Deprivation (national quintiles)</b>		
1 (least deprived)	10,832	24.4
2	10,780	24.3
3	9,651	21.8
4	7,336	16.5
5 (most deprived)	5,764	13.0
<b>Urban Rural classification*</b>		
Urban	33,332	75.1
Rural	11,031	24.9

Notes:

\*See text for definition

**Table 2.** Patient mobility of 44,363 men undergoing radical radiotherapy between 2010 and 2014 in the English NHS: number of hospitals “bypassed” \* and median travel time

Number of hospitals bypassed	Number of patients (%)	Travel time (mins) median (interquartile range)
0	35202 (79.4)	20.7 (12.1 to 32.7)
1	5142 (12.6)	38.3 (23.4 to 53.6)
2	1764 (4.0)	44.0 (22.9 to 59.6)
3	822 (1.9)	46.7 (34.7 to 60.6)
4	308 (0.7)	55.6 (43.3 to 67.3)
≥ 5	1125 (2.5)	52.9 (36.8 to 89.8)

Notes:

\*Hospitals are considered to be “bypassed” if a man has radiotherapy in a hospital that is further away from his place of residence in terms of travel time by car.

**Table 3.** Impact of travel time and hospital characteristics on patient mobility in 44,363 men undergoing radical radiotherapy between 2010 and 2014 in the English NHS.

	Unadjusted Odds ratio (Model 1) *	95% CI	p value‡	Adjusted Odds ratio (Model 2) †	95% CI	p value‡
<b>Impact of additional travel time (mins)</b>	1		<0.001	1		<0.001
<10	0.28	0.27-0.29		0.27	0.26-0.28	
11-30	0.07	0.06-0.07		0.06	0.05-0.06	
31-60	0.006	0.005-0.06		0.005	0.004-0.005	
>60	0.0002	0.0001-0.0002		0.0002	0.0001-0.0002	
<b>Impact of hospital characteristics</b>						
University hospital	1.28	1.26-1.31	<0.001	1.18	1.14-1.23	<0.001
Large scale radiotherapy unit	1.95	1.91-1.99	<0.001	1.55	1.48-1.62	<0.001
Early adopter Intensity modulated radiotherapy	1.15	1.11-1.20	<0.001	1.37	1.30-1.46	<0.001
Hypofractionated treatment (standard)	1.73	1.68-1.78	<0.001	3.10	2.92-3.28	<0.001

**Notes:**

\*Model 1 presents unadjusted odds ratios from the univariate analysis assessing the impact of additional travel time and hospital characteristics on the odds that a patient travels to a particular hospital

†Model 2 presents adjusted odds ratios from the multivariate conditional logit analysis assessing the impact of both additional travel time and hospital characteristics on the odds that a patient travels to a particular hospital.

‡ P value based on likelihood ratio test

**Table 4.** Impact of travel time and hospital and patient characteristics on patient mobility in 44,363 men undergoing radical radiotherapy between 2010 and 2014 in the English NHS.

	Adjusted Odds ratio (Model 3)*	95% CI	p value†
<b>Impact of additional travel time (mins)†</b>			
	1		<0.001
<10	0.18	0.16-0.20	
11-30	0.04	0.04-0.05	
31-60	0.002	0.002-0.003	
>60	0.00006	0.00004-0.00009	
<b>Impact of hospital characteristics</b>			
University hospital	1.19	1.14-1.23	<0.001
Large scale radiotherapy unit	1.56	1.49-1.63	<0.001
Early adopter Intensity modulated radiotherapy	1.37	1.30-1.45	<0.001
Hypofractionated treatment (standard)	3.19	3.01-3.37	<0.001
<b>Difference in impact of additional travel time for selected patient characteristics §</b>			
	<b>Interaction Terms</b>		
Younger patients (< 65 years)			<0.001
<10	1.17	1.07-1.28	
11-30	1.10	1.00-1.21	
31-60	1.42	1.15-1.76	
>60	2.01	1.46-2.77	
Patients without comorbidities			NS
<10	0.95	0.87-1.03	
11-30	0.93	0.85-1.02	
31-60	0.96	0.79-1.17	
>60	1.24	0.94-1.63	
Patients from more affluent areas (IMD 1 or 2)			<0.001
<10	1.26	1.17-1.36	
11-30	1.20	1.10-1.29	
31-60	1.08	0.92-1.29	
>60	1.31	1.05-1.62	
Patients from rural areas			<0.001
<10	2.23	2.04-2.44	
11-30	2.21	2.03-2.42	
31-60	3.21	2.72-3.79	
>60	1.87	1.51-2.33	
McFadden's pseudo R <sup>2</sup>	0.82		

**Notes:**

\* Model 3 presents adjusted odds ratios from the multivariate conditional logit analysis assessing the impact of additional travel time, hospital characteristics and patient characteristics on the odds that a patient travels to a particular hospital.

†Note that the adjusted odds ratios for the impact of additional travel time in model 3 relates to a particular patient group: older men ( $\geq 65$  years), with comorbidity (Charlson  $\geq 1$ ), from less affluent (IMD 3-5), and urban areas

‡ P value based on likelihood ratio test

§ The impact of selected patient characteristics on additional travel time is presented as interaction terms. These should be multiplied with the corresponding adjusted odds ratio for additional travel time to formulate a new odds ratio. Interaction terms can be used in any combination to assess the effect of different patient characteristics on the odds that a patient travels to a particular hospital. For example, the adjusted odds ratios presented (†) relate to older men ( $\geq 65$  years), with comorbidity (Charlson  $\geq 1$ ), from less affluent (IMD 3-5), and urban areas. To calculate the new odds ratio for younger and more affluent men travelling 11-30 minutes, but who still have comorbidity and live in urban areas, multiply 0.04 (travel time adjusted OR for 11-30 minutes) by the corresponding interaction term for men who are affluent (1.20) and men living in rural areas (2.21). The new odds ratio is  $0.04 \times 1.20 \times 2.21 = 0.11$ . i.e. men with these patient characteristics have a greater odds of travelling up to 30 minutes to a particular hospital.



Figure 1.

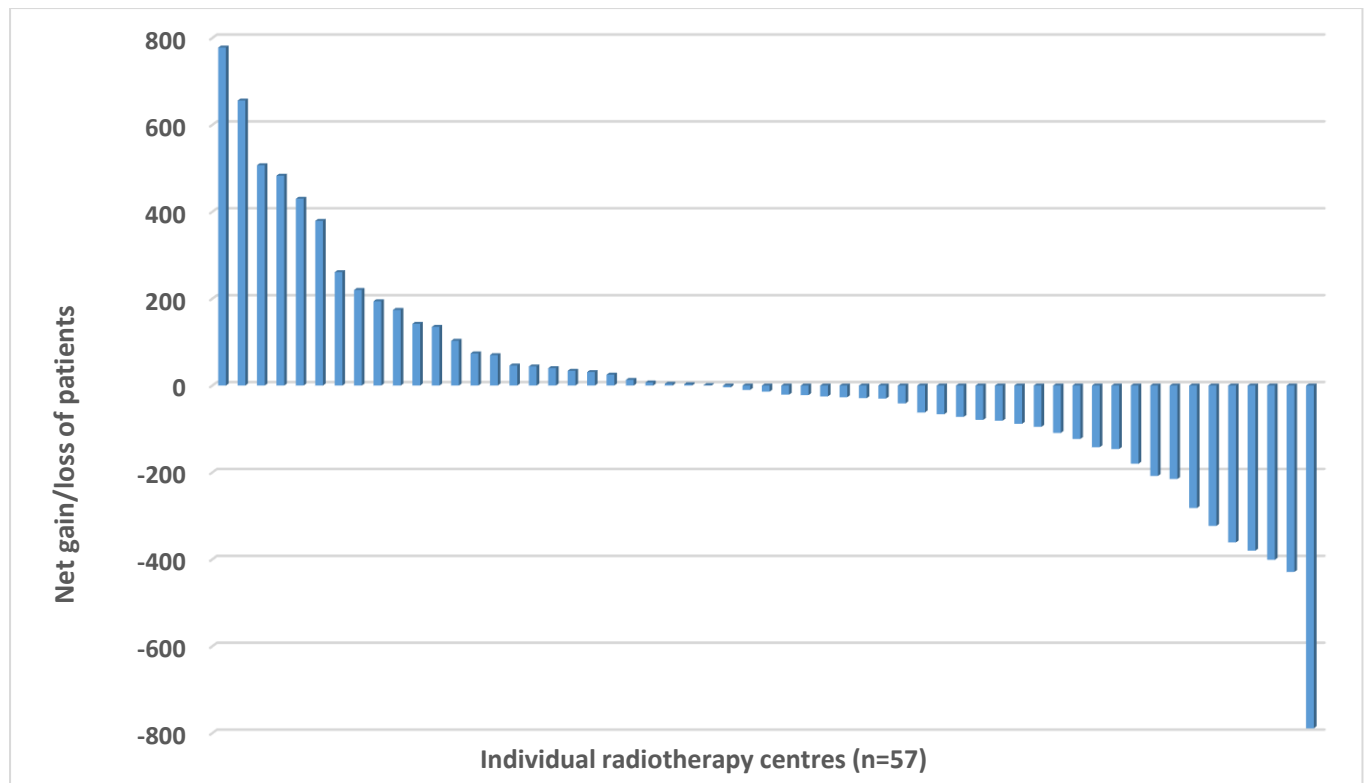


Figure 2.

